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THE AUTOMATION OF THE WISCONSIN ECHELLE SPECTROGRAPH*

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The Wisconsin echelle spectrograph has been placed under computer control. The early operating system and techniques are discussed, as is the automatic data handling afforded by the computer. Some results are shown and future directions are pointed out.

Key words: instrumentation — spectrograph

I. Introduction

The Wisconsin Cassegrain echelle spectrograph has been described by Schroeder and Anderson (1971). We shall note some of the characteristics of the instrument that make it attractive. Since the echelle allows a wide entrance slit, a stellar object may be entirely in the slit if seeing is good. This makes up to some degree for having a modest aperture telescope. The dispersion and resolution possible are similar to those available with a coudé spectrograph. The spectrum is displayed as a raster rather than as a single line which lends itself to image-type devices for detection. If one is to do photoelectric scanning, then it is convenient to limit scanning to a few orders since about 90% of the light of a given wavelength lands in one or two orders. Figure 1 shows the echelle spectrograph schematically. The dispersion and resolution are shown in Figure 2 for several entrance slits.

When considering how to control and operate such a spectrograph, a small computer is a virtual necessity since the Echelle is a quite complex system and the computer allows observing programs to be varied by programming instead of rewiring some electronics. In addition, the data may be quickly reduced and displayed on-line as well as being recorded for future processing.

II. Electronic Data Collection and Control System

The echelle spectrometer system is shown in block diagram form in Figure 3. In addition, the PDP-8 is connected to the automatic 8-inch telescope as described by McNall, Miedaner, and Code (1968).

The heart of the control system is the PDP-8 which has a 4K, 12-bit main core and a 6K auxiliary core. A wide variety of peripheral devices have been added; among them are: a Kleinschmidt printer, Friden punch, Sykes cassette tape recorders, Potter tape reader, sidereal clock, 8-inch telescope and interface, a presettable clock, oscilloscope display, weather instruments, a dataphone, A/D converter and multiplexer, digital multiplexer, and an AC power-switch panel for disabling unused devices. Most of this equipment is military surplus or home built.

Data collection for the echelle starts with two 1P21 photomultipliers — each used in the pulse-counting mode. One photomultiplier continuously views a portion of the incoming photons, thereby acting as an exposure meter. This monitor is actually about 4% of the observed output taken off a semireflective mirror. This small portion of light is coupled to the monitor photomultiplier via a fiber optics bundle. The purpose of the monitor channel is to provide seeing compensation.

The other photomultiplier is positioned behind the exit slit of the spectrometer to detect the signal at the selected order and wavelength. Both signals are sent to preamplifiers and then to a counting instrument: in this case a Digital Synchronous Computer (DSC) Model 1110, manufactured by SSR Instruments. In the normal mode of operation, the DSC is used only as a temporary storage register of both monitor and data counts for a given wavelength and integration time. The stored data are then "read" by the master com-

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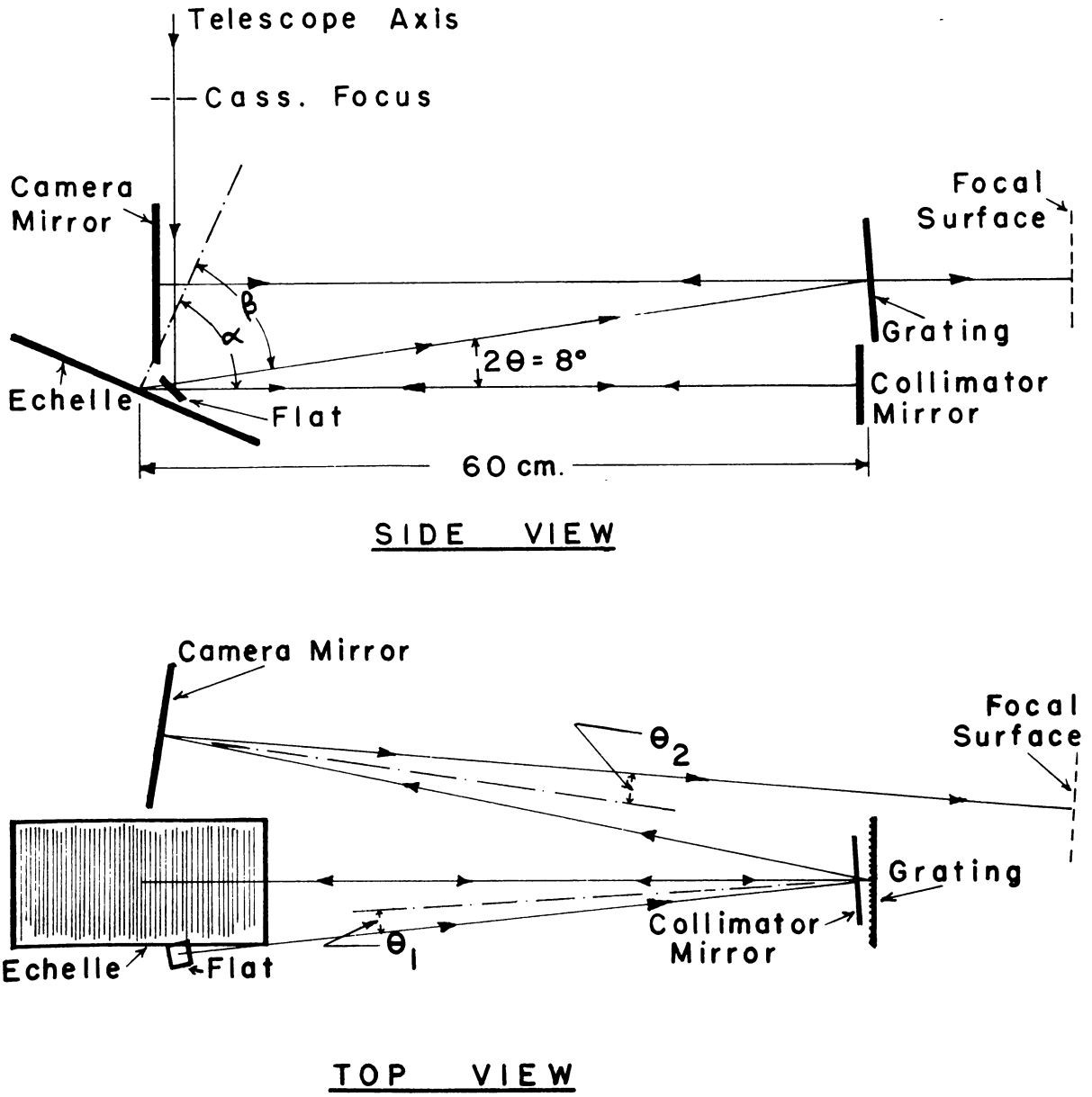

FIG. 1 — Echelle spectrograph schematic: Input beam *f*/13.5. Collimator and camera mirrors are spherical with $f_{col} = f_{cam} = 0.75$ m. $0_1 = 0_2 = 0.06$ radians. Collimator: 75 mm wide by 65 mm high; camera: 120 mm wide by 135 mm high; echelle: 102 mm by 208 mm ruled area; grating: 102 mm square ruled area.

puter, a Digital Equipment Corporation PDP-8, located in the basement of the observatory. The DSC is in itself a rather simple computer which allows the astronomer to manipulate the data to a limited degree. However, for flexibility, the present mode of operation is to have the PDP-8 store and manipulate the data. Of course, the DSC can be operated alone if necessary.

The position of the two gratings is controlled by the stepper motor drive electronics which allows the astronomer to control the gratings either manually or automatically via the computer. The manual mode uses a preset counter arrangement whereas the computer mode moves the gratings on a one step per computer control command basis. Grating position is fed back to

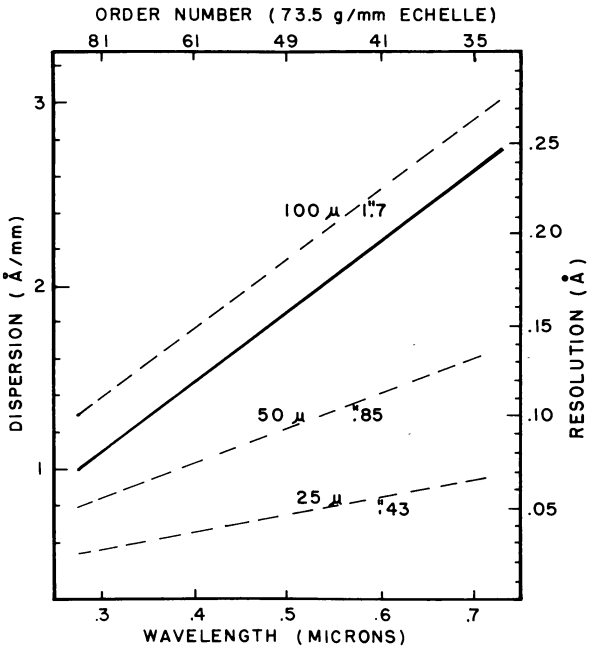

FIG. 2 — The linear reciprocal dispersion in Å/mm as a function of wavelength (in microns) or echelle order number is given by the heavy line and the left scale. The projected slit width in Å for various entrance slit widths (in microns and in arc seconds for a 36-inch *f*/13.5 telescope) is given by dashed lines and the right scale.

the computer by way of two Datex encoders through an interface to the PDP-8. The interface also converts the Datex cyclic code to a decimal code suitable for displaying on readouts in the dome and basement.

All signals passing to and from the dome and basement are fed via twisted pair conductors with digital transmitter and receiver electronics at each end. This technique provides high common-mode noise rejection from external devices within the observatory.

The astronomer has access via the main program to a number of peripheral devices: a high-speed tape reader and punch, a high-speed hard-copy printer and an oscilloscope display for quick analysis of an observed spectrum. Communications with the PDP-8 is via standard ASR-33 teletypes on a question and answer basis. Plate I is a picture of the computer and interface racks in the basement.

III. Programming

The keynote of the programming system is modularity and a monitor operating under in-

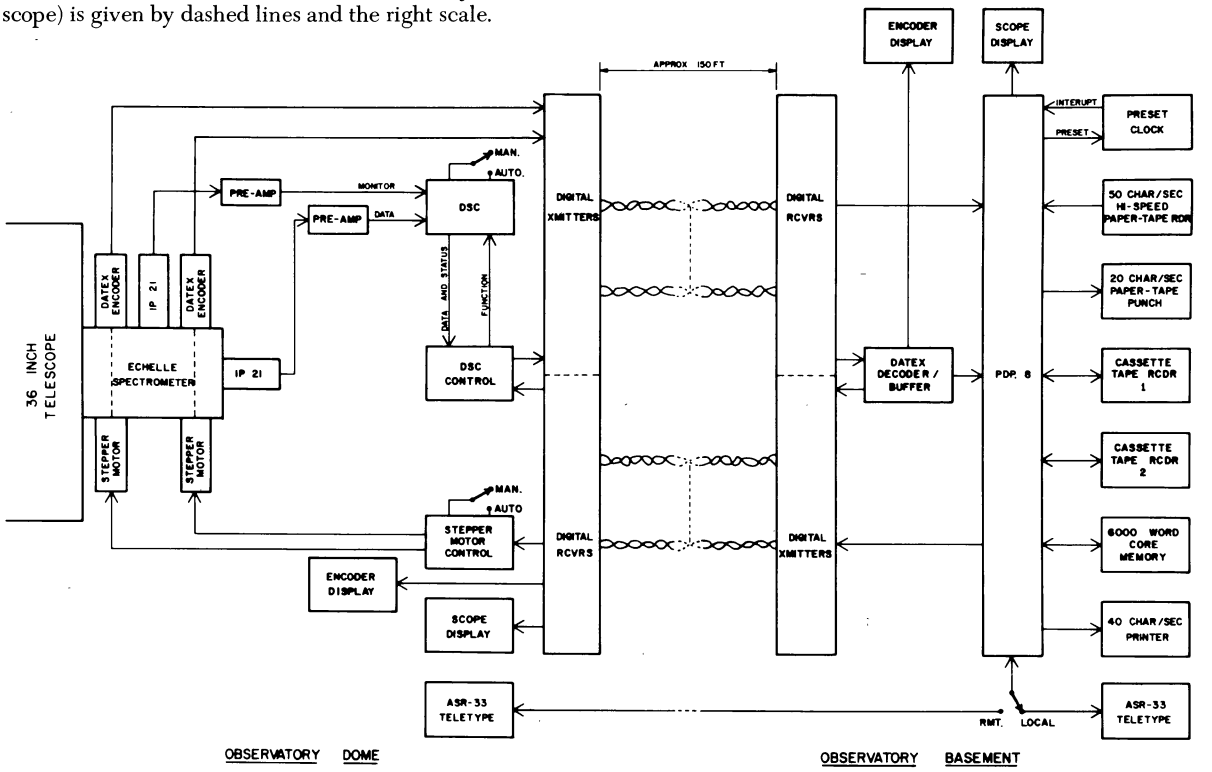

FIG. 3 — Block diagram of automated echelle spectrometer system showing equipment at the telescope and in the basement of the observatory.

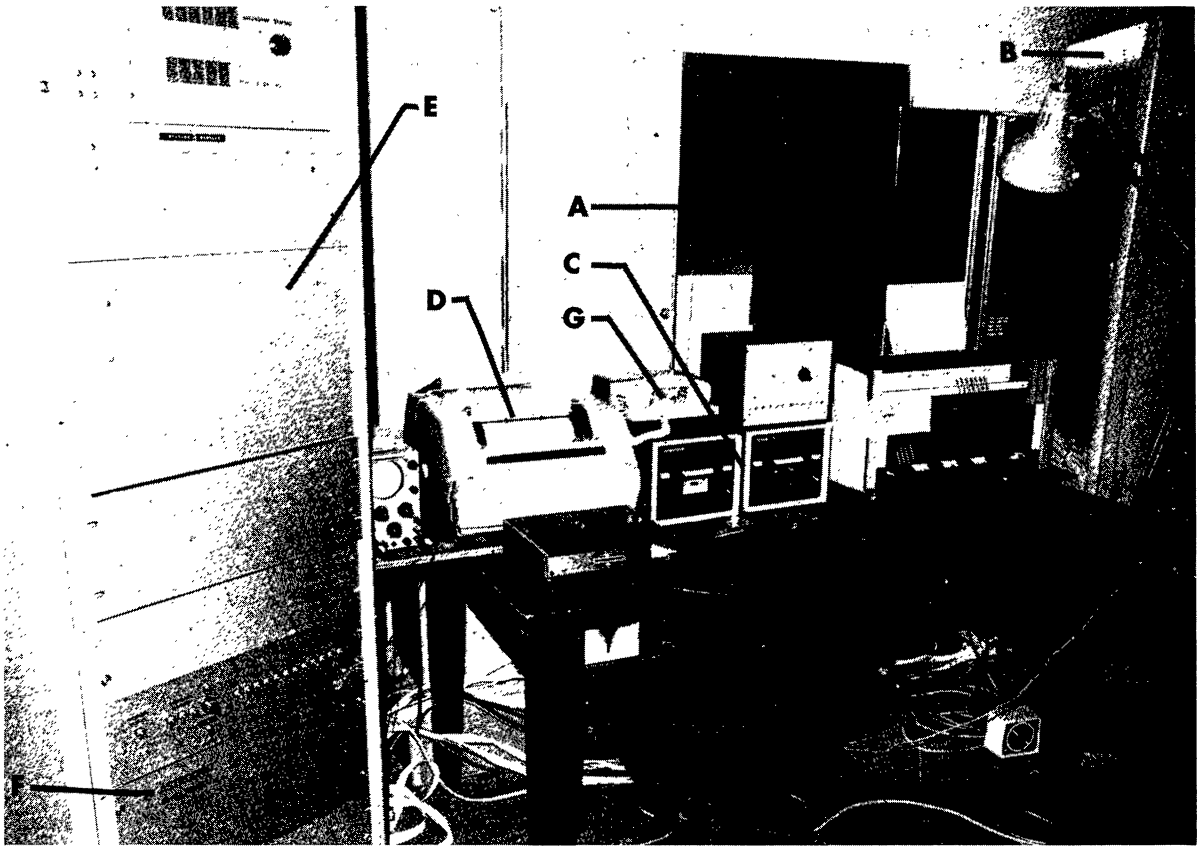

PLATE I

Equipment located in the basement of the observatory including: A) PDP-8 computer; B) interface to automatic 8-inch telescope; C) tape units; D) Kleinschmidt printer; E) interface rack to echelle in the dome; F) extra core unit; G) data-phone.

terrupt control. The modular nature of the programs allows great flexibility and ease of changing the operating main program. This is exceedingly important in a developmental system such as this so that programs can be quickly modified to take advantage of new equipment or operating procedures. The main program contains several different subprograms for different modes of operation. The astronomer selects the subprogram he desires by typing a four-letter code word. The word can designate an automatic-scan mode or a single-step mode. Due to the complexity of the programming and the small PDP-8 storage facility, two Sykes digital cassette recorders are used for storing various programs and observing tables.

Control of the two gratings is done by nulling the encoder readings against the desired position. The motors are started slowly and brought up to high speed by the computer and final positions are approached from the direction of increasing encoder readings with the computer slowing down the drive as null is neared. This gets rid of backlash and shaft twist problems.

The use of the operating program can be demonstrated with a typical observing sequence. To scan a sequence of lines, the astronomer starts the system by loading the main program from cassette recorder No. 1 into the core memory of the PDP-8. This tape is hardware protected against any possible destruction of the program due to operator or computer error. A certain portion of the PDP-8 memory is also wired as a read only memory. This portion contains the loading routines and monitor which allow the astronomer to restore the system without the aid of the programmer.

The user selects a table of wavelengths to be

observed and asks the PDP-8, via the teletype, to read the table from cassette recorder No. 2. New or revised tables can be written onto recorder No. 2 at any time. A table can consist of up to 20 pairs of entries, which comprise an observing program. A pair is a secondary grating position and an echelle encoder position corresponding to a given order and wavelength. Pairs of table entries provide beginning and end points for segments of the spectrum to be scanned. Once the system is loaded, the operator positions the star in the slit and commands the PDP-8 to scan through the table, once or as many times as needed, collecting data from the DSC at each wavelength interval, with or without a printout at each point. If a multiple scan is selected without a printout at each point, the computer automatically averages the data. The operator can terminate, printout, punch, or display the results at any time. He can also add comments to the printout as desired. The table may also be used as a set of discrete wavelengths to be used for line comparison work.

Two changes will soon be implemented. One is to calculate grating and encoder positions for each wavelength in the observing program rather than use a table. This requires a great deal of experience with the encoders and much observing to determine a satisfactory algorithm. The second addition will be to remove the instrumental sensitivity before displaying or printing the results.

IV. Conclusions And Results

The automation of the University of Wisconsin echelle has been accomplished and has been in use several months. The convenience and flexibility are noteworthy. The programming system is experimental and changes are being made as more experience is gained.

For an instrument as complex as this spectrograph it is felt that a control computer is a virtual necessity. It is inadvisable to use too small a machine, however, since the use of such a system and the requirements for handling data are usually underestimated.

Excellent results are being obtained. Figure 4 shows the profile Hβ of α Lyrae as taken by Anderson compared with the data obtained by Baschek and Oke (1965).

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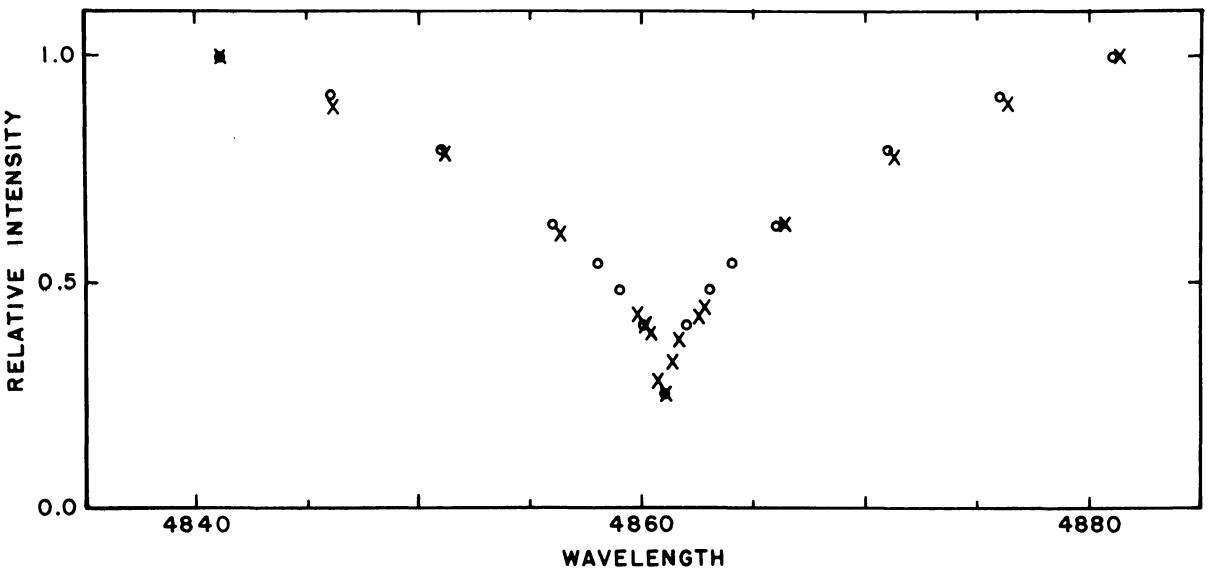

FIG. 4 — The normalized profile of Hβ in Vega. Points marked "X" are the present work, open circles are data of Baschek and Oke (1965).

REFERENCES

Baschek, B., and Oke, J. B. 1965, *Ap. J.* **141**, 1404.
Hoag, A. A., Ball, W. F., and Trumbo, D. E. 1971, *Pub. Roy. Obs. Edinburgh* **8**, 71.
McNall, J. F., Miedaner, T. L., and Code, A. D. 1968, *A.J.* Vol. **73**, No. 9, p. 756.
Schroeder, D. J. 1967, *Appl. Opt.* **6**, 1976.
Schroeder, D. J., and Anderson, C. M. 1971, *Pub. A.S.P.* **83**, 438.